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THE TOTAL ECLIPSE OF THE SUN.

1922 SEPTEMBER 21.

The Sydney Observatory sent an expedition to Goondiwindi, Queensland, and also organised a number of observers at Grafton, New South Wales, and Beaudesert, Queensland, close to the points where the south and north edges of the shadow crossed the 153rd meridian.

At Goondiwindi the programme included—

- A.—Photographs of the stars in the neighbourhood of the eclipsed sun, in order to test the "Einstein effect."
- B.—Observations for local time, and determination of the geographical co-ordinates of the temporary observatory.
- C.—Numerous large-scale photographs of the partial phase, and hence determination of the times of the four contacts.
- D.—Observation of the shadow bands.

At Grafton and Beaudesert the programme included—

- E.—Observation of the shadow bands.
- F.—An attempt to determine the position on the earth of the edge of the moon's shadow.

AT GOONDIWINDI.

A.—*The "Einstein Effect."*

The experience of Greenwich Observatory seemed to indicate that an astrograph, if properly mounted, might be a suitable instrument for the determination of the deviation of a ray of light passing near the sun's limb.

Accordingly our astrograph was removed from Redhill, and rigidly mounted at Goondiwindi, in a spacious galvanised-iron enclosure. A portion of the roof along the meridian from the zenith to the Pole, and a large portion of the western wall were removable.

The only object that seemed at all suitable for a guide-star was β Virginis, but in order to use that it would be necessary to place the axis of the guide telescope out of parallelism with that of the photographic camera. Also there was no certainty that the star would be visible during the eclipse, and much valuable time might be wasted in finding and setting. Upon placing my difficulties before the Astronomer Royal, he advised me to aim rather at securing a perfect drive, so that I could depend upon the star's image remaining accurately bisected by the wire for at least 30 seconds. Unfortunately the driving clock of the astrograph could not be depended upon for such high-class work.

We happened to possess a spare Grubb chronograph, and decided to try to adapt its clock to the astrograph. It was not fair treatment for the clock, as it had been designed to carry a cylinder weighing only a few pounds, and mounted on ball bearings, whereas the astrograph weighs over a ton. An attempt was first made to overbalance the telescope, and use the clock as an escapement. This idea proved to be feasible, but a systematic error appeared in every cycle of 4 minutes, which was eventually traced to inaccuracies in the "back" of the driving worm. Our last hope was that the "front" of the worm might be accurately cut, and that we could compel the clock to drive the great weight. Eventually by overloading the clock and very carefully balancing the telescope when pointed to the eclipse region, we succeeded in keeping a star's image bisected for minutes at a time. It was, however, an unstable arrangement, and occasionally broke down, but mostly gave great satisfaction. The instrument certainly performed better, on the whole, than at any previous time in my experience.

Local supplies of suitable plates are limited in variety, and we were practically compelled to choose between Ilford Special Rapid and Imperial Special Sensitive. A cable was sent to England for a supply of these, but through delay they did not arrive until the day before the eclipse. By that time of course we had decided and taken our comparison plates. The brand we chose was the Imp. S.S.

In preliminary experiments we found it convenient to expose on a portion of the sky at about 3° hour angle. We found that by reducing the aperture to 4 inches we could obtain beautiful images of stars 1, 5, 12, and 17 (see the Astronomer Royal's diagram in Monthly Notices R.A.S. for May, 1920) with 5 seconds exposure. To get measurable images of any others we had to increase the exposure so greatly that I decided to limit our attempts to these four, and take as many different plates as possible.

On the advice of the Astronomer Royal we selected a region having the same R.A. as the eclipse region, and about 5° south. This contained several stars of 6 or 7 magnitude. We proposed to photograph this (which we may call the "test region") both on the comparison and the eclipse plates, and thus obtain measures of any change due to temperature, development, presence of corona, &c., and eliminate it before computing the Einstein displacement.

At this period our prospects seemed distinctly favourable, but when we commenced the actual photography of the comparison plates at the true eclipse altitude we were greatly disappointed. The atmospheric change in $1^{\frac{1}{2}}$ of R.A. was very great. The quality of the images was distinctly inferior; we were compelled to use 7 instead of 4 inches of aperture, and to increase the time of exposure to 10 seconds. We eventually accumulated a passably good series of comparison plates.

Our programme allowed for the taking of eight plates, three of them (Nos. 1, 3, and 5) having the double exposure on eclipse and test regions.

The programme was completed as arranged, but an examination proved that only two of the plates (Nos. 1 and 4) were worth further consideration. The other six showed distinct traces of incorrect clock driving. Some considerable time was spent over the measurement and subsequent computations of plates 1 and 4, but eventually I had to regard them as failures. Although the clock-drive was good, the definition was bad. Some of the images, especially those of Star No. 12, the most important of all, were almost indistinguishable smudges. As criteria of great accuracy they were impossible.

Incidentally, No. 4 produced a fine photograph of the corona.

It is unfortunate that, although used on two eclipse expeditions, the astrograph has not had a fair opportunity of proving its worth for this particular kind of observation.

In 1919 the definition of the images was bad, and this was ascribed to the heating effect of the sun upon the coelostat mirror. In 1922, at Goondiwindi, every precaution was taken to avoid any such effect. The astrograph was solidly mounted on an equatorial stand, of the stable British form, and was enclosed in a spacious observatory. The day was only moderately warm, and the large western opening was protected by a stout canvas blind until a few minutes before totality. Yet the definition was atrocious. In this case, I think, the effect was entirely atmospheric, because the sun's limb, photographed during the partial phase by the photo-heliograph, was also badly defined.

At Christmas Island, where the Greenwich astrograph was stationed, the sky was overcast.

With such evidence it may not be fair to actually condemn the astrograph for future work of a similar description, but from such scrappy accounts as we managed to hear with respect to the magnificent photograph obtained by the Lick expedition at Wollal, it would appear advisable to either use similar instruments to theirs or else leave "Einstein" out of the programme and devote astrographs to work for which they may be more suitable.

Judging by the appearance of the corona on our Plate 1, I might suggest their usefulness in a combined study of this appendage. Of the taking of mere coronal pictures there is no end, and I have no intention of advising simply more pictures. But these thousands of pictures seem to lead to very little, whereas a few dozen, properly taken and co-ordinated, might add considerably to our knowledge.

All astrographs throughout the world have almost identical optical properties, focal length, &c. I would, therefore, suggest that in future eclipses several astrographs, if possible, be used at stations separated as far as may be; that a programme of exposures, ranging from, say, one-fiftieth of a second to five seconds, be mutually arranged, and that exactly similar exposures be made at each station, with strict attention to timing. If all the negatives were then sent to one Central Bureau and carefully compared we should be more likely to advance our knowledge of the structure and formation of the corona than by a hundred times the number of un-coördinated photographs.

B.—Observations of Time, Latitude, and Longitude.

Time.—The Sydney Observatory possesses no field instrument suitable for time observations, yet it was essential to our programme that our chronometers should be properly rated. In an almost forgotten cupboard the old "repeating circle" of Sir Thomas Brisbane was found, covered with rust and dust. This was practically obsolete, even in his time, a century ago, and is almost certainly the most ancient astronomical instrument in Australia. It was cleaned in our workshop and fitted with a new telescope and transit micrometer, and converted into quite a modern form of almucantar instrument. It was then taken to Goondiwindi and mounted on a concrete pier, and used in the determination of time and latitude, according to the method advocated by me in Monthly Notices R.A.S., vol. 63, p. 156, and vol. 64, p. 70. As it is many years since I have had occasion to take this class of observations, I was curious to see how they would turn out under the circumstances, which militated against very accurate work. The instrument was very old and loose in the joints, with plenty of backlash in the screws. It was more or less exposed to the public, and, in spite of all our care, was tampered with almost daily, and the ground proved to be very treacherous, transmitting vibrations altogether too freely. The observations were taken by Mr. Cranney, and must be regarded under the circumstances as very satisfactory. The following are the results of each pair taken on every observing night:—

s.									
23.93	22.45	13.96	12.32	10.08	6.35	4.50	4.64	4.69	2.33
.94	.18	.94	.15	.11	.30	.49	.55	.62	.34
.90	21.99	—	.16	.26	.17	.39	—	.69	.50
—	22.22	13.95	.03	.07	.36	—	4.60	.75	.46
23.92	.24		.16	9.98	.12	4.46		.78	.39
	—		.01	—	.22		—	—	.26
22.22			10.10	—			4.71	—	
			12.14		6.25				2.38

As far as our eclipse observations are concerned, it is evident that we were registering our times well within the second, probably within one or two tenths. Our sidereal clock and chronometers were freely open to the other expeditions situated at Goondiwindi, and were largely used by them.

Latitude.—A few pairs of stars having values of north declination slightly less than ($90^{\circ}-2\varphi$) were observed on four nights for the determination of latitude. The values obtained on the separate nights were:—

28	32	47·4	South.
		46·5	
		47·4	
		46·3	
28	32	46·9	

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The accordance of these, under the circumstances, must be regarded as very satisfactory.

Longitude.—The amateur wireless receiving station of Mr. P. Shaw, a local resident, was kindly placed at our disposal. I wish here to record my grateful thanks to Mr. Shaw, not only for the use of his apparatus, but for his invaluable assistance throughout the campaign. Arrangements had been made, through the courtesy of Captain MacDougall, Superintendent of the U.S. Naval Observatory, for the transmission of special series of time signals at local midnight *via* both New York Radio Central and Annapolis. Unfortunately, the "static" was particularly troublesome, and throughout the entire series we were unable to hear these time signals. Arrangements had also been made, through the courtesy of the Australian Radio Service, for Pennant Hills (near Sydney) to transmit a series of vernier signals. These were easily received at both Goondiwindi and the Sydney Observatory on four nights during which stars were observed at both ends, and the resulting differences of longitude are—

Sept. 15 =	3	36·71
,, 20 =	·50	
,, 22 =	·24	
,, 24 =	·43	
3	36·47	

The separate discordances are rather larger than could be wished, but they seem to occur usually with this class of work, and are always puzzling to account for. The wireless signals were received at both ends by the method described in Monthly Notices, R.A.S., vol. 77, p. 469, and experience with that method has convinced me that it entirely eliminates personal equation and gives a remarkably accurate comparison of the two cloeks. The discordances generally found in even first-class longitude work will probably not be explained until long series of world time-signals have been analysed. For the present the above difference of longitude may be accepted as fairly accurate. Combining it with the adopted value of the longitude for Sydney ($10^{\text{h}} 04^{\text{m}} 49\cdot54^{\text{s}}$), we obtain $10^{\text{h}} 01^{\text{m}} 13\cdot07^{\text{s}}$ for the position of the observing pier at Goondiwindi. It is safe to assume, however, that the adopted value for Sydney requires a correction of about — 0·5 seconds. This has been obtained from several special series sent from Lyons, and received at either Greenwich or Paris and Sydney. Adopting this correction, therefore, we have for the position of the temporary observatory at Goondiwindi—

Longitude— $10^{\text{h}} 01^{\text{m}} 12\cdot6^{\text{s}}$ E.
Latitude— $28^{\circ} 32' 46\cdot9''$ S.

C.—Partial Phase and Times of Contact.

An old photo-heliograph, which was last used for the transit of Venus in 1882, was mounted on an old Grubb 6-inch equatorial stand. The original sliding shutter was out of order, and was not used, but as a substitute a focal plane shutter was mounted immediately in front of the photographic plate. The aperture of the object glass was reduced to $1\frac{1}{2}$ inches, and the diameter of the sun's image was about 4 inches. The slowest plates procurable were used, and the exposure was as rapid as the shutter would permit. Mr. Shaw placed the plate carriers in position and withdrew the dark slide. Mr. Raymond glanced occasionally at the position of the image on the ground glass to see that the clock was driving properly, and made the exposures according to a pre-arranged programme. As time-observing in all its branches is his speciality, we may assume that each exposure was made within a few hundredths of a second of the schedule.

The programme provided for a photograph every two minutes from start to finish, but near the four contacts the interval was reduced to 20 seconds.

During totality four exposures of 2 seconds, 4 seconds, 8 seconds, and 16 seconds, on special rapid isoehromatic plates, were made, but these were outside the special object of the programme, and no results of value were expected or obtained from these four plates.

Altogether 74 photographs were taken, but only a few, near the critical periods, have been measured. For this purpose the star micrometer was used. Each plate was cut to the standard astrograph size, about 6 inches square, care being taken to keep the sun's image in the middle of the plate and oriented so that the cardinal points were parallel to the sides of the plate. It was then placed face to face with a reseau printed on plain glass and placed thus under the microscope. Readings were then taken of the tangent lines at the N., E., S., W. points of the limb, when visible, and of the two "horns" caused by the intersection of the sun's and moon's images.

The following are some of the measures:—S refers to the tangent to the limb at the south point, &c. N-S gives the sun's polar diameter measured in the *x* direction, and expressed in reseau intervals (1 interval = 5 m.m.). E-W gives the equatorial diameter measured in the *y* direction. A and B represent the "lors," both co-ordinates of each point being given. The edge of the sun, under the microscope, looked like a piece of torn blotting-paper. Each plate was measured three times, one complete set of measures (S.N.W.E.A.B.) being taken before the next was started, so as to avoid bias in the individual settings, and these three series are, on the whole, quite unexpectedly accordant, the average difference between any one and the mean of three, from a number of measures selected at random, being only 0·004, or about one five-thousandth of the sun's diameter.

A few individual plates, on the other hand, gave values for the diameter differing considerably from one another. This is specially noticeable in the first three plates, and is probably due to differences in the development. Plate No. 1, in particular, is greatly over-developed. From plates 4 onward the measures of the polar diameter are in good agreement, thus : 21·600, ·604, ·613, ·617, ·604, ·629, ·610, though the equatorial diameter is consistently greater. Also towards fourth contact the measures agree pretty well amongst themselves, though they are all less than near first contact. These little variations will probably scarcely affect the result, except perhaps in the case of time of first contact, but they are mentioned here to call attention to the desirability of taking special precautions to ensure even development throughout in future observations of a similar character.

MEASURES.

Plate No.	N.S.W. Standard Time.	S.	N.	W.	E.	A.		B.	
		x	x	y	y	x	y	x	y
1	3 05 38·0	3·304	25·025	32·363	54·122	16·863	32·750	19·878	34·084
2	6 30·0	·411	25·023	·351	54·167	16·601	32·610	20·472	34·348
3	7 30·0	·233	24·879	·404	54·059	15·694	32·521	20·850	34·812
4	8 30·0	·415	25·015	·376	54·017	15·343	32·436	21·451	35·152
5	10 30·1	·308	24·912	·254	53·976	14·178	32·296	21·881	35·601
6	12 30·1	·414	25·027	·413	54·039	13·639	32·411	22·609	36·387
7	14 30·1	·339	24·956	...	...	12·808	32·547	22·875	36·942
8	16 30·1	·423	25·027	...	...	12·245	32·620	23·288	37·419
33	4 06 30·3	...	...	...	...	3·724	40·616	23·228	49·203
34	08 30·3	...	...	...	...	3·401	42·087	22·163	50·428
35	10 30·3	...	...	...	...	3·520	45·158	19·146	52·836
36	10 50·3	...	...	...	...	3·839	46·368	17·992	53·253
37	11 10·3	...	...	...	...	4·724	48·440	15·775	53·919
44	4 15 30·4	...	...	...	...	10·747	32·931	22·614	36·467
45	15 50·4	...	...	...	...	9·073	33·648	23·781	38·348
46	16 10·4	...	...	...	...	8·184	34·257	24·356	39·632
47	18 10·4	...	...	...	...	5·593	36·670	24·992	43·766
48	20 10·4	...	...	...	...	4·792	37·920	24·801	45·442
73	5 11 10·6	3·353	24·944	...	...	7·135	51·295	14·207	53·953
74	12 10·6	·417	25·000	32·409	53·959	7·663	51·656	13·718	53·933
75	13 10·6	·433	24·962	·418	·870	8·214	52·014	12·884	53·765
76	14 10·6	·377	24·930	·374	·992	9·105	52·658	11·651	53·630
77	14 30·6	·343	24·898	·456	·990	9·590	52·988	10·947	53·509

Near first and last contact the variation of time is proportional to the square of the chord AB. Near second and third contact it is proportional to the width of the crescent, which is computed as follows : If M, S, are centres of moon and sun, and C the centre of AB, then MSC is a straight line which intersects AB at right angles. Continuing this line, let it intersect the moon's limb at J and the sun's at H, then HJ is the width of the crescent, and we have

$$\begin{aligned} SC^2 &= SB^2 - BC^2 & HC &= SB - SC \\ MC^2 &= MB^2 - BC^2 & JC &= MB - MC \\ HJ &= HC - JC \end{aligned}$$

For purposes of computation the sun's semi-diameter (SB) was assumed to be 10·80.

From the N.A. we find sun's true semi-diameter = 956·0"

" " moon's " " " = 1,003·0"

and from p. 378 of Loomis's "Introduction to Practical Astronomy" we find the augmentation of the moon's semi-diameter to be 6·6", making the augmented semi-diameter 1,009·6".

If, therefore, $SB = 10\cdot80$, $MB = 10\cdot80 \times \frac{1009\cdot6}{956\cdot0} = 11\cdot41$, these values of SB + MB, with the measured values of AB, enable us to compute the width HJ for each plate.

Plotting AB^2 as one co-ordinate and the corresponding times near first and last contacts as the other and drawing a straight line graph, the times corresponding to $AB = 0$ were obtained. These, of course, represent moments of first and fourth contacts.

Similarly plotting HJ the moments of second and third contacts were obtained.

Or we may, from each measure and corresponding time, obtain an equation of the form—

$$x - t = my$$

where x = number of minutes from any selected time to time of contact.

t = Do from the selected time to time of observation.

y = measure of AB^2 or HJ.

Using only a few (say, four or five) measures near each contact and solving each set for x , we thus obtain most probable moments of contact.

Omitting Plate 1, for reasons already given, we find a satisfactory accordance between the figures obtained by graph and computation.

Collecting the various results, we have :—

	Predicted.	Observed.					
		By eye.		By graph.		By computation.	
		h.	m.	s.	h.	m.	s.
Time of 1st contact.....	3 05 31.5	3	05	30	3	05	01
" 2nd "	4 11 47.7			.....	4	11	34.8
" 3rd "	4 15 18.5	4	15	08	4	15	09.4
" 4th "	5 14 49.8	5	14	27	5	14	37.3

The last column is the one I recommend for adoption. To obtain G.M.T., subtract 10^h. Comparing the results of observation with the predictions, calculated directly from the British Nautical Almanac, we find :—

Observed—Predicted.

"

1st contact	— 25.5
2nd "	— 13.0
3rd "	— 10.3
4th "	— 12.2

The time of second contact observed by eye was lost through failure of stop-watch to start when pressed. It may, perhaps, be worth while to call attention to the considerable difference between the times of first and last contact, as observed by eye, and as deduced from the photographs. It is, of course, recognised that it is impossible to see the actual tangential contact, but I should scarcely have expected so large a difference as shown. Certainly the limb was boiling, and this may account for it.

I believe Mr. Innes first suggested the present method of determining the times by measuring a few values of the arc (Union Observatory Circular, No. 45), and my experience in this case strongly supports his suggestion.

And now I wish to call attention to a circumstance which surprised me, and which I still find inexplicable. In preparing for the eclipse I was advised by several photographers to either increase the exposure or use more sensitive plates as totality approached, owing to the diminution of light. It seemed to me that my advisers were confusing the photography of the landscape with that of the sun's limb. The latter retains the same intrinsic brilliancy as long as any of it is perceptible. I therefore used the same plates and gave the same treatment throughout. The resulting negatives are equally good and of similar density down to Plate No. 37, which shows a beautiful black crescent 30.8 m.m. from tip to tip and only 0.61 m.m. through at the centre. This was taken at 4^h 11^m 10.3^s, or 24.4^s before second contact. The next plate, No. 38, was taken 20^s later, or 4.4^s before contact, and is perfectly blank. A similar phenomenon occurred near third contact. Plate No. 43 was exposed at 4^h 15^m 10.4^s, or 2 2^s after the sun reappeared. In this case there can be no doubt whatever. Apart from the fact that Mr. Raymond (who made the exposure) is quite unusually expert with respect to any time observations, is his statement that he was waiting, quite prepared, for the exact second by the chronometer when the sudden outburst of light occurred, accompanied by the ejaculation of the crowd of onlookers that surrounded our enclosure. He is absolutely confident that the exposure was made after that moment, and the 2.2^s shown by computation agrees with his mental estimate of the period. This plate also is perfectly blank, whereas No. 44 shows a crescent almost similar to that of No. 37, of excellent density.

Briefly, the puzzle amounts to this: A certain small portion of the sun's limb reproduces itself repeatedly in negative after negative, but fails to do so when its light passes *very close* to the moon's limb, although still easily visible to the naked eye. I calculate that the light from the edge of the sun passed about 2" from the moon's limb at the time of exposure of Plate 38, and 1" at Plate 43, or about 2 and 1 miles away from the moon.

This curious point seems to be worth special investigation in future eclipses. It will be found apparently to recur in a different guise in the discussion of the shadow-edge at Grafton.

D.—*Observation of the Shadow Bands.*

This has produced some interesting reports. Generally the professional astronomers have their attention concentrated upon telescopes or cameras during the period when the shadow bands are passing, and so the observation of this phenomenon has been left to the public at large. As a result of the rather vague statements made by probably thousands of spectators, one gathers that shortly before the commencement of totality alternate bright and dark bands pass rapidly across the earth in advance of the moon's shadow; and follow the retreating shadow after totality. On the present occasion I made arrangements to observe these bands with greater definiteness, and the result has been rather surprising. A strong wooden framework, about 14 feet square, was laid horizontally on the ground, and covered with tightly stretched white calico. Down the middle of this a true meridian was drawn, and upon this line two circles, about 6 feet in diameter, were centred. The circumference of each circle was divided and numbered at every 10°, and a light wooden pointer was pivoted at the centre so as to sweep radially round the circle.

The observers were Mr. W. C. Graham, from the Sydney Observatory, and Dr. Thomson, C.B.E., LL.D., Hon. Secretary of the Royal Geographical Society of Australasia (Queensland). Mr. Graham was provided with a stop-watch, and a chronometer was close handy. Dr. Thompson had a good watch, which was compared with the chronometer just before commencing observation. The instructions were to commence concentrated observation of the white surface at five minutes before totality commenced; to start the watch or note the time at the moment when anything in the nature of bands appeared; to place the pointer parallel to the lines, if they were parallel; and to check off their times by the chronometers. These instructions were faithfully followed, and the reports, written quite independently, are given below.

These speak for themselves. The agreement as to the main facts is remarkable, although in direct opposition to the accumulated impressions of the hundreds of spectators who observed the phenomenon more or less casually, and did not record the exact times of the occurrences. The outstanding feature of Messrs. Graham and Thomson's reports is that the phenomenon is placed *inside* the moon's shadow instead of just outside. The first appearance of the bands occurred at 4^h 12^m 07^s, N.S.W. standard time, and after 2½ minutes the second phase started at 4^h 14^m 35^s, in each case about half a minute inside the shadow. This is opposed to the entire mass of press reports, and to the opinion of everybody with whom I have conversed, yet it seems to me that, under the circumstances, the value of Messrs. Graham and Thomson's reports outweighs all the rest. They were concentrating entirely upon the one observation, snapped their watches at precisely the same moment, and measured the direction of the bands at practically the same azimuth. It is difficult to prove a negative, yet it is more difficult to suppose that these bands were rippling across the sheet for a minute at least before they saw them, and that then they should suddenly see them at the same moment precisely. In any case, the appearance of the second batch is quite positive. These *must* have been visible at the moment noticed. I think that the introduction of the correct time as an element, and the concentration upon the one phenomenon only, gives the observation a value of quite a different order from that of the casual observers, however numerous.

Here follow Messrs. Graham's and Thomson's reports, and the matter will be further discussed in connection with the observations taken at Grafton.

REPORT BY MR. W. C. GRAHAM.

As an amount of uncertainty existed when the shadow bands would arrive, it was thought advisable to concentrate attention on the screen from about five minutes before the computed time of commencement of totality. Stop-watch in hand, their coming was awaited, the light growing dimmer and dimmer. Then quite suddenly across the calico screen very faint bands commenced to ripple. The watch was immediately set going. There was no sign of the bands on the surrounding ground, and this gave the optical effect that the screen itself was in some way disturbed, similarly as one would expect if the timber frame received a light blow. The time of their commencement was 4^h 12^m 7^s p.m., and the angle at which they arrived, taking the mean of the two circles, 341° E.—the pointer on the S circle operated by Dr. Thompson showed 33°, and the N one under my charge showed 36°. Attempts were made to measure the width of the shadows, but they were so fleeting and intangible, without any definite demarcation of boundaries, that it was not possible to obtain a reading, but it was noticed that two bands were moving over a foot scale simultaneously. The first section of the phenomenon lasted about 15 or 20 seconds. Within 2½ minutes the second section commenced. I was engaged at the chronometer when they came, and missed the moment when they touched the screen. I observed the time as 4h. 14m. 40s., which was a few seconds late. The angle at which they came in was 50° E. on both circles. If anything they were even fainter than the first section.

The movement of the bands across the screen appeared somewhat similar to that of vapour rising from a heated plain. After observing these shadow bands one can quite understand why they have not yet been photographed, and I feel quite certain that no photographic plate has yet been made that would succeed in recording them, as seen on the horizontal plane during this eclipse. The speed at which they travelled would have required an exposure of at most $\frac{1}{1000}$ seconds and the different intensity of light and shadow was so slight, added to the absence of sunlight during totality, that their portraiture is beyond the bounds of present photography.

REPORT BY DR. J. THOMPSON, C.B.E., LL.D.

A BETTER place could scarcely have been selected for eclipse observations than Goondiwindi, a municipal town on the McIntyre River, forming the common boundary between New South Wales and Queensland. For miles in all directions the country is flat and covered with stunted scrub timbers locally known as mulga and brigalow, while the river banks are clearly defined in the undiversified landscape by beautiful forest trees towering far above the neighbouring vegetation, and indicating the influence of the fertilising waters of the meandering stream. Climatically the locality is unrivalled for astronomical observations, excepting perhaps at Naples, the rainfall being about 20 inches, and the number of wet days averaging something like fifty, with an extremely low percentage of humidity, September being usually one of the driest months of the year, with not infrequent westerly winds, clear, cloudless sky and keen bracing air. These were the conditions prevailing at Goondiwindi on the occasion of the solar eclipse, 1922, 21st September, when the striking phenomenon in all its phases was observed by organised parties from Sydney and Melbourne. The writer was fortunate in being attached to Professor Cooke's staff, in assisting to observe the so-called "shadow bands," with Mr. Graham of the Sydney Observatory. Shadow waves and ripples would, it is suggested, be more appropriate for this phase of the eclipse, as observed under ideal conditions, with absolutely nothing lacking to secure the best results; for which too much credit cannot be given to the Director of the party and his efficient assistants. The shadows were observed on a specially prepared calico screen, 14 ft. x 13 ft. 9 in., mounted on a wooden frame, bisected by a north and south line, and having on it two large circles graduated from zero to 360 degrees. To each circle was attached a long movable wooden pointer, pivoted in the centre, so as to follow the shadow movements, and indicate accurately their direction and amplitude. Attention was concentrated on the screen some few minutes before totality owing to the uncertainty as to the occurrence of the shadows. In the meantime the sunlight gradually diminished with corresponding fall of temperature, the whole sky assuming a beautiful dark neutral tint, with a clear narrow belt along the surrounding horizon, in striking contrast with the heavenly canopy hanging overhead. With remarkable suddenness and after totality, the faint shadow waves and ripples commenced to flit across the screen in the most fascinating manner, the instant of their appearance being 4^h 12^m 7^s in the direction of S.W. and N.E., say 31 degrees. The waves assumed two distinct and clearly traceable phases, the primary wave being estimated about 4 or 5 inches broad and the second wave being mere ripples not more than half an inch across, and moving along with a peculiar pulsating appearance. This lasted for 18 seconds of time. After an interval of 2½ minutes, and before the end of totality, the second and final shadow phase was observed at 4^h 14^m 35^s, the phenomenon being similar to the first, the only variation being in the increase of amplitude, which in this case reached to 50 degrees east. In general appearance the waves were slightly fainter than during the first phase. The whole phenomena from beginning to end were most remarkable, waves and ripples alike having a singularly elusive appearance, and one could readily understand their disturbing effect on an unseasoned observer or on those of neurotic temperament. To have obtained any clear impression by photographic means would have been quite out of the question as the dim light during the period of totality, the faintness of the shadows and their rapid movements would have rendered success improbable. For similar reasons it seems difficult to understand the practicability of successfully observing and recording these shadow phenomena on walls of buildings, tree trunks and the unprepared surface of the ground, as reported in the Press from several places. Viewed in the light of lifelong experience in celestial observations and as a student of astronomical science the writer cannot do otherwise than express admiration of the full and complete arrangements made by Professor Cooke at Goondiwindi for the very important eclipse work there, and the faultless organisation of his staff, which so materially contributed to the success achieved, while cordial thanks are hereby tendered for the privilege enjoyed as a working member of the party.

E.—Shadow Bands at Grafton.

Grafton is situated on the computed southern edge of the track of the moon's shadow, in longitude 152° 56' E. and latitude 29° 41' S. A meeting of school teachers coincided with the eclipse, and advantage was taken of these facts to organise both teachers and senior High School students for observing the shadow bands and attempting to delineate the exact edge of the moon's shadow on the surface of the ground.

Special observations of shadow bands were made at the Experimental Farm, about 6 miles due north of Grafton. There were two distinct stations, viz.:—

A.—In charge of Mr. G. E. Johns, B.A., B.Sc., the personnel being as follows:—

- (1) Mr. G. E. Johns, B.A., B.Sc., in charge } Observers.
- (2) Mr. H. Harrison, B.Sc., Shire Engineer } Observers.
- (3) Master K. Johnson, science pupil. } Recorders.
- (4) " R. Hundt " "
- (5) Mr. Leslie Johnson, B.A. } Observers for special effects.
- (6) Master R. Attwater.

B.—In charge of Mr. C. G. Lauder, B.Sc., A.A.C.I., the Secretary of the Observation Committee, the personnel being:—

- (1) C. G. Lauder, B.Sc. } To take direction.
- (2) K. Sakini. }
- (3) M. Johnson. } To take times and record.
- (4) J. Reid. }
- (5) E. P. Patterson, B.A. } To take width of bands.
- (6) K. Lauder.

The arrangements generally were in the hands of Inspector R. J. Middleton of Education Department, who gave lectures and inspired great enthusiasm. All shops closed in the town between 3 and 5 p.m., and the whole population watched the unusual spectacle, many travelling a few miles north so as to be sure of seeing the corona. All scientists will appreciate the action of the band of voluntary observers, who deliberately stationed themselves on the edge and outside the zone of totality in order, possibly, to obtain some records of scientific value. Every report indicates this spirit and carries with it internal evidence of a determination to state exactly what the observer saw.

Extracts from Mr. Johns' report:—

The commencement of the shadow bands was not marked by any striking variations in the illumination of the sheet. They began almost imperceptibly, did not travel across the sheet, but shimmered in such a way that the thought came that the effect might be due to a peculiarity of the wind (east wind about 4 miles p.h.) upon the sheet. [cf. Mr. Graham's remarks at Goondiwindi]. This effect reminded me of the uncertain dancing of the waves, especially when the shadows became a little more pronounced. It was not an easy matter to determine the direction of the shadow bands, owing to absence of contrast of light and shade.

It seemed to me that there were *two* trains of waves, travelling in nearly opposite directions. One train soon appeared to predominate, and its rate of travel across the screen was observed (4 feet per minute). This determination taken with stop-watch was a most difficult one—the bands were exceedingly elusive. The reading is given for what it is worth.

After totality the direction of motion of the bands was reversed. The difference may be approximately 160°. Some observers (casual) half a mile nearer the central line—three teachers in fact—found the reversal of the shadow bands, which in their case were clearly defined bands about 14 inches apart, travelling 6 to 12 miles per hour. In their case they are emphatic that the angle between the directions before and after reversal was more like 140°. Moreover it seems that the shadow bands were distinct at points south of our station.

It would be interesting to gather information from observers both North and South of our station with a view to obtaining

- (1) the direction of the motion before and after totality;
- (2) the angle between the respective directions.

By this means some light may be shed upon the cause of the shimmering (stationary wave?) effect.

I did not observe whether the shadow bands period extended into the period of totality. There was no sudden change from light to dark; objects were clearly visible throughout the whole phenomenon.

Mr. Johns gives 4^h. 13^m. 10^s as the approximate estimated time of the first appearance of the bands, but adds: "The bands were so indecisive and showed so little progressive motion that they were not recognised at first as bands. It was estimated that 30 seconds elapsed before the 13^m. 40^s reading was taken." They were travelling north.

The bands reappeared at 4^h. 15^m. 30^s but reversed in direction, now travelling south, and estimated to be moving at the rate of 2 feet per second. They were still visible at 4^h. 16^m. 50^s, but indistinguishable at 4^h. 17^m. 27^s.

Mr. Harrison's report generally corroborates Mr. Johns', but the following extracts may throw a little more light upon some of the features:—

Cessation point (of the first series) was comparatively well marked, being apparently less than one second after totality as it appeared to an observer watching the sheet and not the landscape. Totality also appeared definite in point of time to him. This observation appeared the most definite one of all before totality and the only one at all satisfactory.

The intensity of shadow (relative) increased up to totality, or nearly so.

After totality the direction of movement was approximately north to south, but am not positive about this before the occurrence of stationary waves, which appeared to have been set up as though due to interference. This effect was noted for from 20 to 30 seconds, during which the stable wave length of 18 inches (estimated) occurred for about 15 seconds. There was absolutely no progression of the crests (if a shadow may be termed such) of these stationary waves that could be detected.

B.—Mr. Lauder's report (extracts):—

Just as totality commenced the bands appeared, but were extremely indistinct. The light during totality was that grey peculiar to a heavy thunderstorm, but at no time was it particularly dark. The shadow bands crossed very rapidly at first, but were hardly discernible from the ripples of the canvas, and were only a darker grey than the light. Across the roofs of the buildings, however, they were much more clearly defined.

Before totality they lay in a direction about 20° S. of W., and travelled at right angles to their direction towards the north.

After totality they lay in a direction due E. and W., and travelled due south.

All the bands appeared to travel in straight lines about 14 inches apart.

As the shadow bands were so indistinct their first appearance was unsatisfactory. They were first noted at 4^h. 13^m. 23^s. After totality they commenced at 4^h. 16^m. 8^s, and continued until 4^h. 17^m. 9^s.

SUMMARY.

The above five reports indicate careful observation, concentration upon the subject, and an earnest determination to record the exact facts; yet, whilst agreeing in some particulars, the observers seem to diverge with respect to others. The following is an attempt to summarise the matter:—

All agree that the bands were very faint, ill-defined objects, but yet distinct as parallel bands; so faint as to make it impossible to photograph them. In no case were they seen like the bright lines of Chambers's "Story of Eclipses."

At Goondiwindi the bands were undoubtedly within the moon's shadow.

At Grafton Mr. Lauder's report seems to corroborate this. Although he uses the terms "before" and "after" totality, they are probably intended merely to indicate the first and second series, because he states, "Just as totality commenced, the bands appeared."

The edge of the shadow appears to have passed actually along the river Clarence, which separates Grafton from South Grafton. The bands were well seen in Grafton, but not in South Grafton. On the other hand, Mr. Harrison states: "Cessation point was comparatively well marked, being apparently less than one second after totality to an observer watching the sheet and not the landscape."

The appearance of the bands on the sheet seems to have been far less striking than on the landscape. Mr. Harrison's last words in the paragraph just quoted may possibly suggest a means of reconciling the curious fact that each of six trained observers, looking intently on a surface specially prepared for the purpose, could scarcely distinguish the bands, which appeared to be as obvious as the landscape itself to the casual public. It may be analogous to the view of a large nebula, such as the nebula in Orion, in a telescope. With a low power the merest tyro cannot fail to see the nebula, as the eye takes in the whole nebulous mass, with its variation of light, as contrasted with the blackness of the surrounding sky; but with a high power showing only a small portion of the nebula the total contrast is less, and it may require an experienced observer to even recognise its existence.

The bands, as seen on the sheet, were fairly regular and parallel, and there can be little doubt that the direction in which they lay was accurately recorded. The agreement in this respect is very satisfactory. At Goondiwindi the bearings of the first and second series were N. 34° E. and N. 50° E. At Grafton they were a trifle south of west and due west respectively. It may be interesting to note that the first series at Goondiwindi and both series at Grafton were roughly parallel to the edge of the moon's shadow, but the second series at Goondiwindi differed considerably. The observations of that direction, in particular, are so accordant that we can scarcely question their accuracy.

The direction of motion is in all cases recorded as approximately at right angles to the bands. That could scarcely be otherwise. A series of parallel bands moving systematically in *any* direction would appear to be moving at right angles to that in which they lie, if, as in the present case, there were no spots to arrest the eye.

The "stationary" bands at Grafton seem to me to be particularly interesting. The "interference" explanation suggested by Mr. Harrison deserves consideration, but I should be disposed to attribute their stationary character to the fact that they were moving parallel to their own direction. Let us suppose that the moon's shadow was bordered by a series of relatively light and dark bands (a kind of diffraction effect). Then as this moved westward, and we were able to notice only the component of motion at right angles to the bands, we should see a series of bands at first moving very slowly, then remaining stationary, and then commencing to move very slowly in the reverse direction. This represents just what the Grafton observers seem to have seen, except that one would expect the first movement to have been to the south, and then to the north after the stationary period—just the reverse to what was actually recorded.

The shadow bands still present some baffling problems, and might well be considered as worthy of inclusion amongst the specific objects of observation in future eclipses. I should suggest that views from an elevated site across an extensive plain might be combined with sheet observations, that the sheet be as large as practicable, and that at least two observers be detailed to each sheet, one to be stationed a little above it, so as to command a quick general view of the whole surface, and the other to be down alongside the direction pointer, ready to move it at his own initiative or by dictation from his co-observer. Also that everybody observing the bands should be provided with a means of recording time accurate to a second, and freely introduce the time element into their records.

F.—*The Position of the Edge of the Shadow at Grafton and Beaudesert.*

The general arrangements at Grafton were carried out by a committee, of which Mr. Inspector R. J. Middleton, of the Education Department, was chairman.

A number of interesting reports have been received, from which I shall quote freely before attempting to summarise the results.

Mr. Middleton says:—

Herewith is a report on the arrangements made for the observation of the Solar Eclipse at Grafton, on 21st September. As suggested by you a line of observers was stationed along longitude 152° 56' E. at intervals of 8 chains for a distance of 1 mile north and south of the line latitude 29° 40' 30" S., the calculated edge of the shadow. The stations were pegged out by Surveyor Lindsey, of the Lands Department, and two observers were stationed at each peg. The time signal was arranged by Mr. H. Harding, of Grafton. A gun was fired from the top of the grandstand at the racecourse five minutes before and again at one minute before totality. A flag also was hoisted at the grandstand five minutes before totality. These arrangements were in charge of Mr. G. Thompson, B.A., Mathematical Master, Grafton High School, who had position at station A. His report is attached.

There is no doubt but that the edge of the shadow crossed the eastern end of Susan Island and the edge was clearly seen on the water of the river. I have marked the line on the map attached.

It may be as well to explain that the City of Grafton is situated on the north bank of the river Clarence, that the post office, mill, &c., mentioned by Mr. Tompson (below) are close to the river, the race-course is on the northern boundary of the city, about a mile north of the post office, the parallel of $29^{\circ} 40' 30''$. (computed predicted edge of shadow), runs through about the middle of the racecourse, and the grand stand is a trifle north of this line.

Mr. Middleton places the observed edge of the shadow on a line crossing the extreme southern tip of the city, at a distance of 98 chains south of the above parallel.

Mr. Harding has sent a report wherein he dissents from Mr. Middleton, placing the edge just north of the grandstand and close to the predicted parallel. His report will be found below. The apparently conflicting observations taken on the territory between the grandstand and the water's edge prove to be full of interest. Before offering any comments, I shall permit the observers to tell their own stories.

Mr. Tompson reports:

Observers were stationed at each of the stations 1 to 10 north of the computed shadow line and from A to K south of this line on the meridian.



The reports received from the observers agree, and were as follows:—

- (a) A small portion of the sun was visible, at the moment of complete totality, on the top left-hand side. This may have been a solar prominence.
- (b) The shadow bands were very distinct on the surface of the ground, and on walls, having a wave-like appearance.
- (c) A whitish halo was visible round the moon.
- (d) The shadow swept over, leaving each observer within the shadow belt.
- (e) The totality, if any, was momentary and the light flashed out vividly as the moon appeared to slip off.
- (f) A cold wind blew from the east.

The following information was supplied by observers in the vicinity of the Clarence River, which fixes with certainty the true position of the edge of the shadow.

Mr. Browning, Fraser's Mill, Turf-street, observed with the naked eye, and states:—

- (a) Portion of sun visible at a part corresponding to 11 a.m. on the clock face.
- (b) Shadow bands very distinct on walls.
- (c) A corona visible extending to an apparent length of 7" to 9" measured radially.
- (d) Shadow deepened momentarily.
- (e) Within the shadow belt.

At the same mill, but from the water's edge, Mr. Ebbeling and Mr. H. White record :

- (a) Tip of sun visible, top left-hand corner.
- (b) Shadow-bands clearly seen.
- (c) A glare around the moon at a time corresponding to the total phase.
- (d) Undoubtedly within the shadow, for it grew dark for a few seconds and immediately the flare of light came on.

Mr. Everett, Grafton Post Office, states :—

- (a) Sun completely covered for a second.
- (b) Shadow bands very distinct.
- (c) Pink (dull) halo round the moon.
- (d) The place darkened for a few seconds, and then the light flashed out again.

Sergeant McAlpin, from a position in Victoria-street, in front of the post office, states :—

- (a) Sun not completely eclipsed and appeared like a diamond ring with the claw setting at a position corresponding to 9 or 10 on the clock face.
- (b) Pink glow round the moon.
- (c) Shadow bands rippled down the street eastward.
- (d) Within the shadow.

Constable L. R. McLeay, situated on the river bank in Duke-street, saw the shadow cross the river. This statement is corroborated by a man who was with him at the time, and who is also attached to the Grafton Police Station. He records :—

- (a) The shadow swept across the river from a point north of the shed on Susan Island to the foot of Duke-street where he was standing. South of this line the water was clear, but north of it it was dark.
- (b) South Grafton houses were very distinct, whereas the Grafton buildings near at hand were seen in a light corresponding to late twilight.
- (c) Shadow bands were visible north of this line, but were not noticed south of it.
- (d) A slight halo round the edge of the moon.

Mr. Mackie, engine-driver of the punt stationed at South Grafton, made observations through a dark glass all the time, and records :—

- (a) The shadow swept over Grafton north of his position like a smoke screen.
- (b) No shadow bands were noticed.
- (c) The water to the north of Susan Island was dark, whereas on the south side of the island it was clear.
- (d) The sunlight came forth suddenly.

Eight miles from South Grafton on the railway line the sun shone all the time, and at Coramba it appeared like a new moon at the time of the total eclipse farther north.

Dr. Maxwell, of Clarence House, South Grafton, reported that the eclipse was not total there.

The observations made at Fraser's Mill, the post office, and Duke-street on the river bank, were made with the naked eye at the time of the total phase. The observations from the south side were made with coloured glass owing to the brightness.

GEORGE THOMPSON.

All of the above reports agree in placing the edge of the shadow along the river, as shown in the sketch. On the other hand, Mr. Harding's report, taken alone, would place the edge just north of the grandstand on the racecourse, and a little more than a mile north of Mr. Middleton's position.

Mr. Harding is a leading watchmaker of Grafton, and kindly undertook to give the time signals for Mr. Middleton, as indicated. His interest was keenly aroused, and he arranged for a few independent observers. These were men of excellent standing, and his report deserves consideration equally with those of Mr. Middleton. At first sight the two seem to be in contradistinction, but as both are honest attempts to state exactly what was seen, we must regard them as different faces of the truth, and endeavour to reconcile them.

Mr. Harding reports :—

Grafton, 25th September, 1922.

It has been suggested that I should furnish you with particulars of the eclipse which have come within my notice, bearing upon the latitude of the margin of the shadow.

Mr. Inspector Middleton asked me to arrange a time signal for the observers on the racecourse. Having got standard time and supplied it to local observers, and to Mr. Marks, of the Experiment Farm, I stationed one of my employees on the grandstand of the racecourse, with a stop-watch, with instructions to carefully note the progress of the eclipse, and take the duration of the total phase.

He carried out his part carefully, but had no occasion to stop the watch, as the sun was not at that station ever fully eclipsed. He states that the crescent of light shrank until it was a thin line, when it became a brilliant spark of light like Venus, got smaller, then increased in size and again became crescentic, but never entirely disappeared.

He says that when the last crescent was just visible a "fringe" of light appeared on the dark (north) side of the black moon, extending outwards to about the length of the moon's semi-diameter, and this "fringe" spread round the moon on either side towards the star of light on the edge of the moon (south), but did not reach quite round, its length becoming less until it faded away altogether before reaching the lighted side. He likens the appearance of the corona as a light shining through the mane of a horse from behind.

Another observer, Mr. S. Philips, survey department, was stationed on the roof of his residence in Victoria-street, about 6 chains north of the river. His description is substantially the same, except that the corona was in his case not so pronounced, showing more dark gaps in it, but more fully developed on the north side of the moon. He called his wife's attention to it, and she had just time to see it, when it died out. They estimate the time of its duration as from 5-10 seconds, and both are, as in the case of the observer at the racecourse, emphatic that the light of the sun never quite disappeared, but glowed like a small brilliant star and then increased, without at any time going out.

I have also asked many other people whom I could rely upon who were within the town boundary at the time, and all are unanimous that the sun's light was never entirely extinguished, but that a starlike spark of light was visible at the least luminous moment.

Many people say they saw a fringe of light about the sun at the time, but also saw the remaining bright spark—one expressing surprise that so small a part of the sun could be so intense in its light.

Two days later (27th September), Mr. Harding wrote:—

Following what I wrote yesterday, I have now found one man who stationed himself 300 yards due north of the racecourse, and he states that the last spark of the sun's glow disappeared and reappeared almost instantly. He is Mr. Olling, school teacher, Education Department. He knew what he was to look for, and so was particular in noting the momentary totality. This is quite in accordance with the report of my own man a few hundred yards further south, where the sun just escaped being eclipsed totally.

On 11th October Mr. Harding further reported:—

I am enclosing a paper sent to me by Mr. Holmes, the District Surveyor, which will explain itself. My observer on the stand was 5° north of Mr. Lindsay's station, in both of which cases the eclipse was not total. But Mr. Olling was, as stated, 300 yards due north of the racecourse, the boundary of which is about 100 yards north of the grandstand. Mr. Olling was, therefore, about 400 yards north of my man, where, according to him, the eclipse was momentarily total.

Mr. Lindsay's letter, forwarded through Mr. Holmes, is as follows:—

The eclipse was observed from a point X on attached litho, approximately on lat. $29^{\circ} 40' 30''$ S. and 77 chains east of long. $152^{\circ} 56'$ E.

The eclipse was not total at this point, part of the sun being always visible in the position "10 o'clock," appearing to the naked eye like a miniature sun.

Shadow bands were observed as the sun began to get clear, moving directly north and rapidly, and resembled an elongated shadow cast by a picket fence, the width of the shadow bands and the spaces between the bands appeared about 9 inches.

Finally Mr. Harding later interviewed Mr. Mackie, stationed at South Grafton (*vide supra*), and says:—

It is quite clear that this band or strip of light was nothing but a line of light reflected from the ripples on the water, from the smaller visible part of the sun, just as Venus makes. My conversation with him convinces me that what he saw had nothing to do with the shadow, and that the appearance of the sun was much the same there as in other parts of Grafton. It is evident that the edge of the shadow was north of Grafton, and south of the Junction Hill.

These two reports (let us refer to them as M. and H.) appear at first sight to be hopelessly contradictory, but I think they will be found to agree in the essential observed facts. The divergencies occur in the interpretation of the facts. Let us first summarise what the observers saw:—

- M.—(a) Eclipse was total from a little north of the grandstand northwards.
- (b) Eclipse was not total from South Grafton southwards.
- (c) The full black moon, surrounded by a corona, was visible as far south as the Grafton Post Office—*i.e.*, practically throughout the whole of Grafton.
- (d) A small portion of the sun was visible, "at the moment of complete totality," on the top left-hand side.
- (e) The edge of the shadow was seen along the river and crossing a few yards of the extreme south tip of the city.

H. agrees with (a) (b) (c) (d), but thinks Mr. Mackie may have been mistaken with respect to his observation of (e). On the other hand are the statements of Constable McLeay, and another police officer, definitely corroborating Mr. Mackie's report.

The statements of the facts actually witnessed by M. and H. are therefore in exact agreement, but the interpretation differs. We may accept with certainty that the shadow came south within, say, half a mile of the grandstand, and did not reach any point of South Grafton. Our task is to assign a definite position within those limits for the shadow-edge.

Is there a shadow-edge? If so, how can it be defined (1) theoretically, (2) practically?

(1) Refers this difficulty still further back, viz., to the edge of the sun. Is there an edge to the sun itself sufficiently definite for our purpose?

This is answered in the affirmative by the photographs of the partial phase taken at Goondiwindi. If, then, we imagine a cone enveloping both sun and moon the locus of the most southerly point of the curve formed by the intersection of the cone and the earth's surface is the line we wish to locate. I believe this should be a fairly definite line. Whether it can be *seen* as such is another matter. This brings us to—

(2) The actual determination of the line.

We need now consider only the debatable area, which is practically the City of Grafton. From almost exactly the same premises M. deduces that totality covered the city, and H. that it stopped short at the northern edge. M. had one extra piece of evidence, the actual visibility of the shadow-edge on the river, and I confess that this seems to me very important. Eliminating it for a moment, let us see, in a nutshell, what appears to be the rival views.

M. says: "The whole moon became visible, also the corona, a twilight gloom covered the city, to be succeeded almost instantly by a sudden outburst of light; therefore during the gloom the sun was eclipsed, notwithstanding the fact that there was always a bright spot at the top left-hand corner."

H. says: "We watched the sun's light gradually diminishing, but at the minimum there was always a small but brilliant point of light. Therefore the eclipse was not total, notwithstanding the fact that we saw the entire round of the black moon and the corona."

Which is correct? I have just made the following experiment. Standing just within the shadow of an E.-W. wall I protected my eye with a piece of dark glass and looked in the direction of the sun. I first moved my head outwards until I could just see a tiny portion of the sun projecting beyond the parapet, then reversed the motion until the sun's limb was *just* cut off. In this position there was certainly none of the sun showing, but there was a very bright spot or very small line of light *on the edge of the parapet*. My own answer to the above query is that Mr. Middleton's position of the shadow-edge is correct; that is, that the edge of the shadow passed about 100 chains south of its predicted position and cut the meridian of $152^{\circ} 56'$ E. in lat. $29^{\circ} 41' 35''$ S.

OBSERVATIONS AT BEAUDESERT.

Beaudesert is a small town in Queensland, situated in lat. $27^{\circ} 59'$, long. $152^{\circ} 56'$. It does not possess a High School, but I interviewed Mr. Stanley, headmaster of the State School, who promised to place a number of his oldest and brightest pupils at distances of a furlong apart along a road passing in a more or less north-south direction, the central point being the railway station, lat. $27^{\circ} 59' 12''$, through which passed the predicted position for the shadow-edge. Mr. Stanley was absent from Beaudesert at the time of the eclipse, but the observations were carried out as arranged, under the superintendence of Mr. George Crawford.

All reports agree that the sun was not totally eclipsed within the limits of this string of observers; that is, that the shadow-edge passed south of lat. $28^{\circ} 00'$.

Two reliable youths went as far south as Mount Mahomet (lat. $28^{\circ} 07'$, long. $153^{\circ} 01'$), where the eclipse was total, the totality lasting for $1^m 10s$.

Combining both sets of observations (Grafton and Beaudesert) it appears that the shadow was about 100 chains south of its predicted position.

SUGGESTIONS.

When an observation of this kind occurs only once in a lifetime it is difficult to prepare a working programme. After the event one feels that if he could start afresh, he could do at least some things differently. We ourselves are not likely to observe another total eclipse, but for the guidance of those who may the following suggestions are offered :—

1. Above all things arrange for a time service, accurate to 0·5 s., and see that this element is included in the report of every item.

If the position of the observer is known, and is within 2,000 or 3,000 miles of a powerful time-distributing radio station, the time may be conveniently obtained by means of a portable wireless set.

Otherwise, if it is necessary to observe stars for determination of clock error, I strongly recommend the alnucantar method described in Monthly Notices R.A.S., p. 156.

2. If the altitude of the sun is less than 30° do not attempt observations of star positions so delicate as those necessary for the "Einstein effect."
3. The astrograph has not yet had a fair trial. From all accounts the telescopes specially designed and used by the Liek observers are ideal, but everybody cannot have access to such perfect instruments. There are a number of astrographs which may be available, and if one of these can be transported and properly mounted, equatorially, in a suitable locality, it would be well worth a trial.
4. There are two distinct methods of taking these special observations. Dr. Campbell believes in long exposures and large plates, so as to obtain a great number of stars on each plate, and doubtless, for his instruments, his judgment is perfectly sound. The Astronomer Royal prefers short exposures and plates 8 by 8 inches, using working fields of about 6 by 6 inches. This means few stars and more plates. For the astrograph, I strongly indorse his methods. In fact I am inclined to add :—Reduce the aperture of the O.G. to 4, or at the most 5, inches, and do not exceed 10 s. exposure. If under these conditions it is not possible to obtain at least four well-distributed stars within a radius of $1^{\circ} 40'$, the observation should not be attempted.
5. The Astronomer Royal's suggestion of a "test" field is an excellent one. Select a region, say, between 5° and 15° distant from the eclipse region, in declination, and with the same R.A. as the sun, or *vice versa*, and containing at least five or six stars of the 8th mag., or brighter, within the above limits (radius, $1^{\circ} 40'$). By suitable means, such as temporary stops attached to the declination circle, arrange to move the telescope smoothly and rapidly from one region to the other. Include at least three double exposures (*i.e.*, on both test and eclipse regions) in the comparison and eclipse series of plates. These test regions will be used to determine whether any changes due to temperature, &c., have occurred between the comparison and eclipse plates.
6. Every photograph of the corona should have a specific purpose. I suggest the use of three or four similar instruments, such as the astrograph, located as far apart along the path of totality as possible, with an exactly similar programme at each station, say, with exposures ranging from 0·05s. to 10s.
7. Photographs of the partial phase with images of the sun not less than $1\frac{1}{4}$ inches in diameter should be taken, very accurately timed, so as to obtain times of the contacts. Near first and last contacts I should recommend six at intervals of 20^s . Near third and fourth contacts it would be an excellent thing to take a considerable number at one second intervals, if possible. An explanation of the two blank plates, one 4^s . before totality commenced, and the other 2^s . after the sun burst forth, ought to be sought. Light may also be thrown upon the interesting phenomena observed at Grafton city. I should suggest the use of films, with an automatic release, once a second, controlled by a clock pendulum. A photographic reproduction of the seconds hand of the clock or a rated chronometer on each photograph would be highly desirable. There should be no doubt as to the exact time when each plate is exposed.
8. It would be an excellent thing to correlate the above series with another arranged to catch the exact moments of appearance and disappearance of the flash spectrum. This indicates a fairly definite part of the sun.
9. Special care should be taken with the development of the plates in No. 6, so as to secure uniformity.
10. It is well worth while to detail one or more experienced observers to note the shadow bands. Three series of observations should be correlated—(a) Watching the surface of a tightly-stretched white sheet from close quarters, as carried out by Messrs. Graham and Thomson (see p. 5); (b) watching the same sheet from a little height above it; (c) watching the landscape from an elevation. If a suitable site be available (b) and (c) might be undertaken by the same person. A transit observer, who is accustomed to eye and ear work, or somebody with a similar training, should be selected.

He should be provided with a rated chronometer, suitably lighted, so that he can pick up the second about five minutes before totality, and carry on the count whilst he watches the sheet or landscape, or both. At the first certain appearance of the bands he should notify (*a*) and book the time. The observer (*a*) may or may not see them, but he also should book the time when they first become visible, and set the pointer along their direction.

Similar observations should be made near third contact.

11. A piece of useful information would be the general intensity of the light at mid-eclipse—not accurately measured and expressed in terms unintelligible to the average person, but in some such manner as this: Equivalent to 25 minutes after sunset on a clear summer evening. For this purpose I suggest a simple arrangement like a box camera without a lens, the plate-holder consisting of a printing frame, in which is placed a slow plate behind a "Primus printing gauge." The effect of this, when exposed to the light, is to produce a series of figures, 1, 2, . . . , the number depending upon the duration and intensity of the light. Experiments should be made at different times after sunset and with different exposures, but from some made by ourselves, I suggest 30". exposure on a slow plate during eclipse, and then the same exposure at 20", 25", 30", 35" after sunset.
12. I would strongly advise the selection of a location close to the shadow-edge, with a large number of observers, who should be thoroughly intelligent, but need not be specially trained. There should, however, be a skilful astronomer in personal charge.

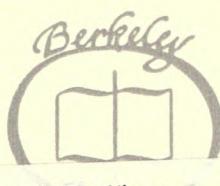
The arrangements as carried out by the various committees at Grafton were excellent, and might be accepted as a model. We require to add something in order to deal specially with the interesting points raised.

And once again the introduction of accurate time throughout is the first essential. The arrangements made by Mr. Harding are now found to be insufficient. By some means or other every observer or group of observers should note the time, accurate at least to 1 second, of every event recorded.

Then the same arrangement as to observation of shadow bands suggested in No. 9 should be adopted. Also special observers should be detailed to ascertain the north or south limits of the bands. We are informed, for example, that they were seen all over Grafton, but not at South Grafton, but have no evidence that they were specially looked for at the latter place. It would be a piece of important information to know whether they are or are not seen beyond the limits (north or south) of the moon's shadow.

Systematic attempts should be made to see the edge of the shadow on the ground. Eye observations similar to those made at Grafton, along a line of at least 2 miles at right angles to the shadow track, should be taken. These ought to be supplemented by photographs. If possible some such automatic arrangement as suggested in No. 6 might be used at three (or five) localities, one on the predicted edge of the shadow, and the others 1 (or 2) mile inside and outside.

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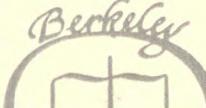
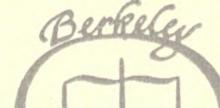
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